SEMESTER VII

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U40A	ADVANCED CONTROL SYSTEMS	PCC	2	1	0	3	2020

i) **PRE-REQUISITE:** EE1U30C: Signals and Systems, EE1U30E: Linear Control Systems.

ii) **COURSE OVERVIEW**: This course introduces advanced concepts in control theory to the students to enable them to design a controller required for a control system. The course also presents the concept of state feedback controllers and their design. A brief introduction to state space approach of digital control system is also covered. Apart from these, non-linear systems and its analysis using different methods are also discussed in the course. It thus helps the students to get an overview of the advanced concepts and enables them to apply these advanced control principles in various areas of industry.

iii) **COURSE OUTCOMES**

After the completion of the course, the student will be able to:

CO1	Develop the state variable representation of physical systems.	Apply
CO2	Use state variable approach to analyse the performance of linear and nonlinear systems	Apply
CO3	Design state feedback controller for a given system.	Apply
CO4	Explain the characteristics of nonlinear systems.	Understand
CO5	Apply the tools like describing function approach or phase plane approach for assessing the performance of nonlinear systems.	Apply
CO6	Apply Lyapunov method for the stability analysis of physical systems.	Apply

iv) **SYLLABUS**

State Space Representation of Systems, Examples of electrical circuits and dc servomotors, Phase variable forms of state representation - Diagonal Canonical forms - Similarity transformations to diagonal canonical form.

State Space Analysis: State transition matrix – Properties, Computation of state transition matrix using Laplace transform and Cayley Hamilton method. Derivation of transfer functions from state equations.

Solution of time invariant systems, State space analysis of Discrete Time control systems, Pulse transfer function from state matrix, Computation of State Transition Matrix.

Controllability & observability, Duality principle, State feed-back design via pole placement technique. State observers for LTI systems – types - Design of full order observer.

Nonlinear Systems: Types and characteristics of nonlinear systems, Describing function method, Determination of describing function of nonlinearities, Application of describing function for stability analysis of autonomous system with single nonlinearity.

Phase plots, Definition of stability - asymptotic stability and instability, Construction of phase trajectories using Isocline method for linear and nonlinear systems, Lyapunov stability analysis.

v) (a) TEXT BOOKS

1) Nagarath I. J. and Gopal M., "Control System Engineering", 5th Edition, New Age Publishers, 2007.
2) Ogata K., "Modern Control Engineering", 5th Edition, Prentice Hall of India, 2010.
3) Gopal M, "Modern Control System Theory", 2nd Edition, New Age Publishers, 1984.
4) Kuo B.C, "Analysis and Synthesis of Sampled Data Systems", Prentice Hall Publications, 2012.

(b) REFERENCES

1) Khalil H. K, "Nonlinear Systems", 3rd Edition, Prentice Hall, 2002.
2) Gibson J.E., "Nonlinear Automatic Control", Mc Graw Hill, 1963.
3) Gopal M., "Control Systems: Principles and Design", 4th Edition, Tata McGraw Hill, 2012.
4) Slotine J. E and Weiping Li, "Applied Nonlinear Control", Prentice-Hall, 1991,
5) Gopal M, "Digital Control and State Variable Methods", 2nd Edition, Tata McGraw Hill, 2003.
6) Thomas Kailath, "Linear Systems", Prentice-Hall, 1980.
7) Ogata K., "Discrete Time Control Systems", 2nd Edition, Pearson Education, Asia, 2015.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**State Space Representation of Systems:** Introduction to state space and state model concepts - state equation of linear continuous time systems, matrix representation- features - Examples of electrical circuits and dc servomotors. Phase variable forms of state representation, Diagonal canonical forms of state representation - Diagonal & Jordan forms, Similarity transformations to diagonal canonical form.	**8**
II	**State Space Analysis:** State transition matrix - Properties of state transition matrix - Computation of state transition matrix using Laplace transform - Cayley Hamilton method, Derivation of transfer functions from state	**10**

	equations, Solution of time invariant systems: Solution of time response of autonomous systems and forced systems. State space analysis of Discrete Time control systems: Phase variable form and Diagonal canonical form representations, Pulse transfer function from state matrix - Computation of State Transition Matrix - (problems from 2nd order systems only).	
III	**State Feedback Controller Design:** Controllability & observability: Kalman's, Gilbert's and PBH tests- Duality property, State feedback design via pole placement technique, State observers for LTI systems - Full order and reduced order observers- Design of full order observer design Simulation using MATLAB/SIMULINK.	**7**
IV	**Nonlinear Systems:** Types of nonlinear systems- characteristics of nonlinear systems- peculiar features like Jump resonance, Limit cycles and Frequency entrainment. Describing function Method: Analysis through harmonic linearisation Determination of describing function of nonlinearities. Application of describing function for stability analysis of autonomous system with single nonlinearity (relay, dead zone and saturation only).	**8**
V	**Phase Plane and Lyapunov Stability Analysis** Phase plots: Concepts- Singular points - Classification of singular points. Construction of phase trajectories using Isocline method for linear and nonlinear systems, Definition of stability - asymptotic stability and instability. Phase Plot Simulation using MATLAB/SIMULINK. Lyapunov stability analysis: Lyapunov function - Lyapunov methods to stability of nonlinear systems. Lyapunov methods to LTI continuous time systems.	**12**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U41A	ELECTRIC DRIVES	PEC	2	1	0	3	2020

i) **PRE-REQUISITE:** EE1U30G: Power Electronics, EE1U20D: DC Machines and Transformers. EE1U30D: Synchronous and Induction Machines

ii) **COURSE OVERVIEW**: The goal of this course is to expose the students to the basic concepts of Electric Drives. It also includes the speed control methods of DC and AC drives. The course also provides an insight on the basic concepts of space vectors.

iii) **COURSE OUTCOMES**

After the completion of the course, the student will be able to:

CO1	Describe the transient and steady state aspects of electric drives.	Understand
CO2	Apply the appropriate configuration of controlled rectifiers for the speed control of DC motors.	Apply
CO3	Identify the different quadrant operation of chopper-fed DC motor drive.	Apply
CO4	Illustrate the various speed control techniques of induction motors.	Understand
CO5	Examine the vector control of induction motor drives.	Understand
CO6	Distinguish different speed control methods of synchronous motor drives.	Understand

iv) **SYLLABUS**

Block diagram of electric drives- fundamental torque equations, types of loads – classification of load torque, four quadrant operation of drives, Equivalent values of drive parameters - steady state stability.

Rectifier control of DC drives- separately excited DC motor drives using single-phase and three phase controlled rectifiers - dual converter control of DC motor - circulating current mode.

Chopper control of DC drives - two quadrant and four quadrant chopper drives - motoring and regenerative braking -closed loop speed control for separately excited dc motor.

Three phase induction motor drives: Stator voltage control - Stator frequency control – v/f control - static rotor resistance speed control– static slip power recovery scheme.

Concept of space vector – Clarke and Park transformation – field orientation principle – Introduction to direct vector control of induction motor drives-Synchronous motor drives self-controlled mode – load commutated CSI fed synchronous motor.

v) (a) TEXT BOOKS

1) G. K. Dubey, "Fundamentals of Electric Drives", Naroda publishers, 2nd Edition, 2001
2) Bimal K. Bose, "Power Electronics and Motor Drives", Academic press, An Imprint of Elsevier, 2006.

(b) REFERENCES

1) Vedam Subrahmanyam, "Electric Drives Concepts and Applications", MC Graw Hill Education, 2nd Edition, 2011, New Delhi.
2) Dr. P. S. Bimbhra, "Power Electronics", Khanna publishers, 5th Edition, 2012.
3) Ned Mohan, Tore M Undeland, William P Robbins, "Power electronics converters applications and design", John Wiley and Sons Inc.,3rd Edition, 2009.
4) Muhammad H. Rashid, "Power Electronics, Devices, Circuits and Applications", Pearson, 3rd Edition, 2014
5) R Krishnan, "Electric Motor Drives: Modeling, Analysis, and Control", Prentice Hall, 2001.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to electric drives – block diagram – advantages of electric drives – dynamics of motor load system, fundamental torque equations, types of loads – classification of load torque, four quadrant operation of drives, Equivalent values of drive parameters- effect of gearing - steady state stability.	**9**
II	Rectifier control of DC drives- separately excited DC motor drives using controlled rectifiers- single-phase fully controlled rectifier fed drives (discontinuous and continuous mode of operation), critical speed - single-phase semi converter fed drives (continuous mode of operation) - three-phase semi converter and fully controlled converter fed drives (continuous mode of operation) - dual converter control of DC motor - circulating current mode.	**9**
III	Chopper control of DC drives - two quadrant and four quadrant chopper drives - motoring and regenerative braking - chopper fed DC series motor drive - closed loop speed control for separately excited dc motor.	**9**
IV	Three phase induction motor drives: Stator voltage control - Stator frequency control – v/f control - below and above base speed – Voltage Source Inverter (VSI) fed v/f control using sine-triangle PWM - static	**9**

	rotor resistance speed control employing chopper – static slip power recovery speed control scheme for speed control below synchronous speed.	
V	Concept of space vector – Clarke and Park transformation – field orientation principle – Introduction to direct vector control of induction motor drives – decoupling of flux and torque components - space vector diagram and block diagram Synchronous motor drives – v/f control – open loop control – self-controlled mode – load commutated CSI fed synchronous motor.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U41B	DIGITAL CONTROL SYSTEMS	PEC	2	1	0	3	2020

i) **PRE-REQUISITE:** EE1U20A: Circuits and Networks, EE1U30C: Signals and Systems, EE1U30E: Linear Control Systems.

ii) **COURSE OVERVIEW**: This course aims to provide a strong foundation in discrete domain modelling, analysis and design of digital controllers to meet performance requirements.

iii) **COURSE OUTCOMES**

After the completion of the course, the student will be able to:

CO1	Explain the various control blocks and components of digital control systems.	Understand
CO2	Use z-domain techniques to analyse sampled data systems	Apply
CO3	Design a digital controller/ compensator in the frequency domain.	Apply
CO4	Design a digital controller/ compensator in the time domain.	Apply
CO5	Develop controllers for linear discrete time systems using state variable concepts.	Analyse

iv) **SYLLABUS**

Basic digital control system - Mathematical modelling - sampling and reconstruction - Zero order and First order hold circuits - realisation of digital filters. Relation between transfer function and pulse transfer function - Mapping between s-domain and z-domain.

Pulse transfer function of different configurations of systems - Modified z-transform -Time Response of discrete time system.

Design of controller/Compensator in frequency domain - Bilinear transformation and sketching of frequency response. Introduction to design and simulation using MATLAB.

Design of controller/Compensator based on time response, Design of controllers and compensators by the method of Ragazzini - Introduction to Dead beat response and deadbeat controller design.

Modern control approach to digital control - Introduction to state space - Computation of solution of state equation and state transition matrix. Controllability, observability and stability of discrete time systems. Digital controller and observer design.

v) (a) **TEXT BOOKS**

1) C. L. Philips, H. T. Nagle, “Digital Control Systems”, Prentice-Hall, Englewood Cliffs, New Jersey, 1995.

2) M. Gopal, "Digital Control and State Variable Methods", Tata McGraw-Hill, 1997.
3) Ogata K., "Discrete-Time Control Systems", Pearson Education, 2nd Edition, 2005.

(b) REFERENCES

1) Benjamin C. Kuo, "Digital Control Systems", 2nd Edition, Saunders College Publishing, Philadelphia, 1992.
2) Constantine H. Houpis and Gary B. Lamont, "Digital Control Systems Theory", Hardware Software, McGraw Hill Book Company, 1985.
3) Isermann R., "Digital Control Systems: Fundamentals, Deterministic Control", V. I, 2nd Edition, Springer Verlag, 1989.
4) Liegh J. R., "Applied Digital Control Theory, Design and Implementation,", Dover Publishers, 2nd Ed. ISBN13-.**978-0486450513**
5) Åström, Karl J., and Björn Wittenmark, "Computer-controlled systems: Theory and design", Courier Corporation, 2013.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Basic digital control system- Mathematical modeling - sampling and reconstruction - Zero order and First order hold circuits - realisation of digital filters. Relation between transfer function and pulse transfer function - Mapping between s-domain and z-domain.	**9**
II	Pulse transfer function of different configurations of systems- Modified z-transform-Time Response of discrete time system. Order and Type of a system Steady state error and Static error constants.	**8**
III	Bilinear transformation and sketching of frequency response - Digital P/PI/PID controller design based on frequency response - Digital compensator based on frequency response. Introduction to design and simulation using MATLAB (for demo/ assignment only and not to be included for examination).	**10**
IV	Design of lag, lead and lag-lead compensator using root locus - Design of controllers and compensators by the method of Ragazzini- Dead beat response controller introduction.	**8**
V	Introduction to state space - state space modeling of discrete time SISO system - Computation of solution of state equation and state transition matrix. Controllability, observability and stabilizability of discrete time systems- Loss of controllability and observability due to sampling.	**10**

	Digital controller and observer design - state feedback – pole placement - full order observer - reduced order observer.	
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

3) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U41C	MODERN OPERATING SYSTEMS	PEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil

ii) COURSE OVERVIEW: The goal of this course to understand the concepts of OS through process/threads, system call interface, deadlock, scheduling, address space, main memory and file systems.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Describe the key concepts of modern operating systems.	Understand
CO2	Apply the concepts of scheduling and process synchronization for process management.	Apply
CO3	Explain the various memory management techniques.	Understand
CO4	Illustrate different file management and directory management methods.	Understand
CO5	Explain Disk scheduling and RAID structures.	Understand

iv) SYLLABUS

Operating System Concepts – Operating System Structure - Operating System Operations.

System Structures: System Calls - Types of System Calls, System Programs, Operating-System Design and Implementation.

Process Management: Process Concept, Operations on Processes, Interprocess communication, Threads Overview, Process Scheduling: Scheduling Criteria, Scheduling Algorithms, Mutual exclusion - Algorithms, semaphores, Deadlocks.

Memory Management: Swapping - Contiguous Memory Allocation- Paging - Page tables – Page replacement algorithms.

File Management: File Concept - File Sharing – Protection - File-System Implementation - File-System Structure - Directory Implementation, Disk Scheduling - RAID Structure.

Protection and Security: Goals of Protection, Principles of Protection, Domain of Protection, Access Control, The Security Problem, Program Threats, System and Network Threats.

v) (a) TEXT BOOKS

1) Abraham Silberschatz, Peter B. Galvin, Greg Gagne, “Operating System Concepts”, 10th Edition, Wiley publishers, 2018.

(b) REFERENCES

1) William Stallings "Operating Systems: Internals and Design Principles", 7th Edition, Prentice Hall, 2012.

2) Andrew S. Tanenbaum, Herbert Bos, "Modern Operating systems", 4th Edition, Pearson publications, 2015.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction** – Operating System Concepts – Operating System Structure - Operating System Operations, Process Management - Memory Management - Storage Management - Protection and Security. **System Structures**: System Calls - Types of System Calls, System Programs, Operating-System Design and Implementation.	9
II	**Process Management**: Process Concept – Operations on Processes – Interprocess communication, Threads Overview - Multithreading Models. **Process Scheduling**: Basic Concepts - Scheduling Criteria - Scheduling Algorithms - First come first served scheduling - Shortest job first - Round robin scheduling. **Mutual exclusion**: Algorithms, semaphores, Introduction to Deadlocks.	9
III	**Memory Management**: Swapping - Contiguous Memory Allocation-Paging - Page tables – Page replacement algorithms - Optimal page replacement algorithm - First-in first-out algorithm - Second chance page replacement algorithm, Clock Page Replacement algorithm.	9
IV	**File Management**: File Concept - Access Methods - Directory and Disk Structure - File-System Mounting - File Sharing – Protection - File-System Implementation - File-System Structure - Directory Implementation - Allocation Methods - Free-Space Management - Efficiency and Performance.	9
V	**Mass Storage Structure**: Disk Scheduling - RAID Structure. **Protection and Security**: Goals of Protection - Principles of Protection - Domain of Protection - Access Matrix - Implementation of Access Matrix - Access Control - The Security Problem - Program Threats - System and Network Threats.	9
	Total hours	45

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 arks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U41D	DATA STRUCTURES	PEC	2	1	0	3	2020

i) PRE-REQUISITE: ES0U10E: Programming in C.

ii) COURSE OVERVIEW: This course aims at moulding the learner to understand the various data structures, their organization, and operations. The course helps the learners to assess the applicability of different data structures and associated algorithms for solving real world problems efficiently. This course introduces abstract concepts for data organization and manipulation using data structures such as stacks, queues, linked lists, binary trees and graphs for designing their own data structures to solve practical application problems.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Develop an algorithm for a computational task and calculate the time/space complexities.	Apply
CO2	Identify suitable data structure (array or linked list) to represent a data item required to be processed to solve a given computational problem and write an algorithm to find the solution of the computational problem.	Apply
CO3	Develop an algorithm to find the solution of a computational problem by selecting an appropriate data structure (binary tree/graph) to represent a data item to be processed.	Apply
CO4	Apply appropriate Hash Function to store a given dataset and enable efficient access of data in the given set.	Apply
CO5	Make use of appropriate sorting algorithms based on specific circumstances.	Apply

iv) SYLLABUS

Introduction: Basic Concepts of Data Structures, Algorithms, Performance Analysis, Asymptotic Notation, Complexity Calculation of Simple Algorithms.

Arrays and Searching: Sparse matrix, Stacks and Queues, Linear Search and Binary Search.

Linked List and Memory Management: Operations on Linked List, Types of Linked Lists, Stacks and Queues, Memory allocation and deallocation - First-fit, Best-fit and Worst-fit.

Trees and Graphs: Binary Trees, Binary Search Trees, Graph Representations, Depth First Search and Breadth First Search, Applications of Graphs.

Sorting and Hashing: Selection Sort, Insertion Sort, Quick Sort, Merge Sort and Heap Sort, Hashing Techniques, Collision Resolution, Overflow handling, Hashing functions.

v) (a) TEXT BOOKS

1) Ellis Horowitz, Sartaj Sahni and Susan Anderson-Freed, "Fundamentals of Data structures in C", Universities Press, 2nd Edition, 2008.

(b) REFERENCES

1) Samanta D., "Classic Data Structures", Prentice Hall India, 2009.
2) Richard F. Gilberg, Behrouz A. Forouzan, "Data Structures: A Pseudocode Approach with C", 2nd Edition, Cengage Learning, 2005.
3) Aho A. V., J. E. Hopcroft and J. D. Ullman, "Data Structures and Algorithms", Pearson Publication, 2001
4) Tremblay J. P. and P. G. Sorenson, "Introduction to Data Structures with Applications", Tata McGraw Hill, 1984.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Introduction: Basic Concepts of Data Structures, System Life Cycle, Algorithms, Performance Analysis, Space Complexity, Time Complexity, Asymptotic Notation, Complexity Calculation of Simple Algorithms.	9
II	Stacks, Queues-Circular Queues, Priority Queues, Double Ended Queues, Evaluation of Expressions, Linear Search and Binary Search.	9
III	Linked List and Memory Management: Self-Referential Structures, Dynamic Memory Allocation, Operations on Linked List-Singly Linked List, Doubly Linked List, Circular Linked List. Stacks and Queues using Linked List, Polynomial representation using Linked List.	9
IV	Memory allocation and deallocation-First-fit, Best-fit and Worst-fit allocation schemes. Trees and Graphs: Trees, Binary Trees-Tree Operations, Binary Tree Representation, Tree Traversals, Binary Search Trees- Binary Search Tree Operations.	9
V	Graphs, Representation of Graphs, Depth First Search and Breadth First Search on Graphs, Shortest-path algorithms, Minimum spanning tree, Prim's and Kruskal's algorithms, Applications of graphs.	9
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U41E	DIGITAL SIGNAL PROCESSING	PEC	2	1	0	3	2020

i) PRE-REQUISITE: EE1U30C: Signals and Systems.

ii) COURSE OVERVIEW: This course introduces the discrete Fourier transform (DFT) and its computation using direct method and fast Fourier transform (FFT). Techniques for designing infinite impulse response (IIR) and finite impulse response (FIR) filters from given specifications are also introduced. Various structures for realization of IIR and FIR filters are discussed. Detailed analysis of finite word-length effects in fixed point DSP systems is included. Architecture of a digital signal processor is also discussed.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Construct Discrete Fourier transform and Fast Fourier transform.	Apply
CO2	Describe the various structures for realization of IIR and FIR discrete-time systems.	Understand
CO3	Develop IIR (Butterworth and Chebyshev) digital filters using impulse invariant and bilinear transformation methods.	Apply
CO4	Develop FIR filters using frequency sampling method and window function method.	Apply
CO5	Compare fixed point and floating point arithmetic used in digital signal processors and discuss the finite word length effects.	Understand
CO6	Explain the architecture of digital signal processors and the applications of DSP.	Understand

iv) SYLLABUS

Discrete-Fourier Transform - Review of signals and systems - Frequency domain sampling - Discrete Fourier transform (DFT) – inverse DFT (IDFT) - properties of DFT -Filtering of long data sequences - Fast Fourier transform (FFT).

Realization of IIR and FIR Systems - Introduction to FIR and IIR systems - Realization of IIR systems - conversion of lattice to direct form and vice-versa - signal flow graphs and transposed structures - Realization of FIR systems.

IIR Filter Design - Design of IIR filters - frequency transformation in analog domain - design of LP, HP, BP, BS IIR digital filters using impulse invariance and bilinear transformation.

FIR Filter Design and Representation of Numbers - Impulse response of ideal low pass filter - Design of FIR filter using window functions (LP, HP, BP, BS filters) - FIR filter design based on frequency sampling approach (LP, HP, BP, BS filters).

Representation of numbers – fixed point representation - floating point representation – IEEE 754 32-bit single precision floating point representation.

Finite Word Length Effects and Digital Signal Processors - Digital signal processor architecture based on Harvard architecture - extended parallelism - comparison of fixed-point and floating-point processor - applications of DSP.

v) (a) TEXT BOOKS

1) John G. Proakis & Dimitris G. Manolakis, "Digital Signal Processing Principles, Algorithms & Applications", Prentice Hall International Inc., 3rd Edition,1996.

(b) REFERENCES

1) Emmanuel Ifeachor & Barrie W Jervis, "Digital Signal Processing", Pearson, 13th Edition, 2013.
2) P. Ramesh Babu, "Digital Signal Processing", Scitech Publications (India) Pvt Ltd, 2nd Edition, 2003.
3) Li Tan, "Digital Signal Processing, Fundamentals & Applications", Academic Press, Ist Edition, 2008.
4) D. Ganesh Rao & Vineeta P Gejji, "Digital Signal Processing, A Simplified Approach", Sanguine Technical Publishers, 2nd Edition, 2008.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Discrete-Fourier Transform-Review of signals and systems - Frequency domain sampling - Discrete Fourier transform (DFT) – inverse DFT (IDFT) - properties of DFT – linearity, periodicity, symmetry, time reversal, circular time shift, circular frequency shift, circular convolution, complex conjugate property – Filtering of long data sequences – over-lap save method, over-lap add method – Fast Fourier transform (FFT) – advantages over direct computation of DFT - radix -2 decimation-in-time FFT (DITFFT) algorithm, Radix-2 decimation-in-frequency FFT (DIFFFT) algorithm.	9
II	**Realization of IIR and FIR Systems-**Introduction to FIR and IIR systems - Realization of IIR systems – direct form 1, direct form 2, cascade form, parallel form, lattice structure for all-pole system, lattice-ladder structure – conversion of lattice to direct form and vice-versa - signal flow graphs and transposed structures – Realization of FIR systems – direct form, cascade form, lattice structure, linear phase realization.	9

III	**IIR Filter Design -**Conversion of analog transfer function to digital transfer function – impulse invariant transformation and bilinear transformation – warping effect. Design of IIR filters – low-pass, high-pass, band-pass, band-stop filters – Butterworth and Chebyshev filter – frequency transformation in analog domain - design of LP, HP, BP, BS IIR digital filters using impulse invariance and bilinear transformation.	**9**
IV	**FIR Filter Design And Representation Of Numbers-**Impulse response of ideal low pass filter – linear phase FIR filter – frequency response of linear phase FIR filter – Design of FIR filter using window functions (LP, HP, BP, BS filters) – Rectangular, Bartlett, Hanning, Hamming and Blackmann only – FIR filter design based on frequency sampling approach (LP, HP, BP, BS filters).Representation of numbers – fixed point representation – sign-magnitude, one's complement, two's complement – floating point representation – IEEE 754 32-bit single precision floating point representation.	**9**
V	**Finite Word Length Effects and Digital Signal Processors-**Finite word length effects in digital Filters – input quantization – quantisation noise power – steady-state output noise power – coefficient quantisation – overflow – techniques to prevent overflow - product quantization error – rounding and truncation – round-off noise power – limit cycle oscillations – zero input limit cycle oscillations – overflow limit cycle oscillations – signal scaling. Digital signal processor architecture based on Harvard architecture (block diagram) – Harvard architecture, pipelining, dedicated hardware multiplier/accumulator, special instructions dedicated to DSP, replication, on-chip memory cache, extended parallelism- comparison of fixed-point and floating-point processor – applications of DSP.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U41F	ILLUMINATION TECHNOLOGY	PEC	2	1	0	3	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: The basic objective of this course is to deliver the fundamental concepts of illumination engineering in the analysis and design of architectural lighting systems.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Explain the fundamental concepts of natural and artificial lighting schemes.	Understand
CO2	Apply the laws of illumination and concept of polar curves for the calculation of illuminance at a point.	Apply
CO3	Design efficient indoor lighting systems.	Apply
CO4	Design efficient outdoor lighting systems	Apply
CO5	Identify suitable control methods for lighting and demonstrate various features of aesthetic lighting.	Apply
CO6	Explain the fundamental concepts of natural and artificial lighting schemes.	Understand

iv) SYLLABUS

Types of illumination, Day lighting, Artificial light sources - Quality of good lighting, shadow, glare, reflection, Colour rendering and stroboscopic effect, Lighting schemes.

Luminous intensity, Lumen, Candle power, Illumination, M.H.C.P, M.S.C.P, M.H.S.C.P, Lamp efficiency, Laws of illumination, Illumination at horizontal and vertical plane from point source, Concept of polar curve.

DLOR and ULOR, Selection of lamp and luminance, Calculation of wattage of each lamp and no of lamps needed, Layout of lamp luminaire, staircase, Corridor lighting and industrial building.

Street Lighting - Types of streets and their level of illumination required, Selection of lamp and luminaire, Calculation of illumination level available on road. Tunnel Lighting, Flood Lighting.

Special Features of Aesthetic Lighting: Monument and statue lighting, Sports lighting, Hospital lighting, Auditorium lighting, Lighting controllers – dimmers, motion and occupancy sensors, photo sensors and timers. Lighting system design using software.

v) (a) TEXT BOOKS

1) D.C. Pritchard, "Lighting", Routledge, 6th Edition, 2014.
2) Jack L. Lindsey, "Applied Illumination Engineering", Prentice-Hall; 1st Edition, 1991.

(b) REFERENCES

1) John Matthews, "Introduction to the Design and Analysis of Building Electrical Systems", Springer, 1993.
2) M.A. Cayless, "Lamps and Lighting", Routledge, 1996.
3) Craig DiLouie, "Advanced Lighting Controls: Energy Savings, Productivity, Technology and Applications", CRC Press, 2005.
4) R. H. Simons and A. R. Bean, "Lighting Engineering Applied calculations", Routledge; 1st Edition, 2020.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction of Light:** Types of illumination, Day lighting, Artificial light sources- artificial lighting and total lighting, Quality of good lighting, Factors affecting the Physical processes- Incandescent and Halogen lamps, Fluorescent lamps, LPSV and HPSV lamps, mercury vapour lamps, metal halide lamps, LED lamps- modern trends. Supplementary lighting-shadow, glare, reflection, Colour rendering and stroboscopic effect, Methods of artificial lighting, Lighting systems-direct, indirect, semi direct, semi-indirect, Lighting scheme, General and localized.	9
II	**Measurement of Light:** Definition of luminous flux, Luminous intensity, Lumen, Candle power, Illumination, M.H.C.P, M.S.C.P, M.H.S.C.P, Lamp efficiency. Laws of illumination- Inverse square law and Lambert's Cosine law, Illumination at horizontal and vertical plane from point source, Concept of polar curve, Measuring apparatus- Goniophotometer, Integrating sphere, lux meter.	8
III	**Design of Interior Lighting:** Definitions of maintenance factor, Uniformity ratio, Direct ratio, Coefficients of utilisation and factors affecting it, Illumination required for various work planes, Types of fixtures and relative terms used for interior illumination such as DLOR and ULOR, Selection of lamp and luminance. Determination of Lamp Lumen output taking into account voltage and temperature variations, Calculation of wattage of each lamp and no of lamps needed, Layout of lamp luminaire, Calculation of space to mounting height ratio, Indian standard recommendation and standard practices for	10

	illumination levels in various areas, Special feature for entrance, staircase, Corridor lighting and industrial building.	
IV	**Design of Outdoor Lighting:** Street Lighting - Types of streets and their level of illumination required, Terms related to street lighting, Types of fixtures used and their suitable application, Various arrangements in street lighting, Requirements of good street lighting, Selection of lamp and luminaire, Calculation of illumination level available on road. Tunnel Lighting, Calculation of their wattage and number and their arrangement, Calculation of space to mounting height ratio. Flood Lighting: Terms related to flood lighting, Types of fixtures and their suitable applications, Selection of lamp and projector, recommended method for aiming of lamp, Calculation of their wattage and number and their arrangement, Calculation of space to mounting height ratio.	**10**
V	**Special Features of Aesthetic Lighting:** Monument and statue lighting, Sports lighting, Hospital lighting, Auditorium lighting General Aspects of emergency lighting. Lighting controllers – dimmers, motion and occupancy sensors, photo sensors and timers. Lighting system design using software (eg: DIALux and Relux). Note: Case study of indoor and outdoor lighting design using software may be given as assignment.	**8**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U41G	DIGITAL PROTECTION OF POWER SYSTEMS	PEC	3	0	0	3	2020

i) **PRE-REQUISITE:** EE1U30A: Power Systems I, EE1U30F: Power Systems II.

ii) **COURSE OVERVIEW**: The basic objective of this course is to deliver fundamental concepts to design various electronic circuits to implement various relaying functions. The relays such as Static Relays, Microprocessor based protective relays, Digital relay Travelling wave-based protection and adaptive relaying is comprehensively covered in this course. It should be also useful to practicing engineers and the research community.

iii) **COURSE OUTCOMES**

After the completion of the course, the student will be able to:

CO1	Classify the relay protection scheme suitable for over current, differential and distance protection.	Understand
CO2	Develop the protection scheme for bus bars, transformers, generators, motors and distribution systems using appropriate protective relays.	Apply
CO3	Illustrate the operation of a numerical relay in his/her own way.	Understand
CO4	Explain signal processing methods and algorithms in digital protection.	Understand
CO5	Infer emerging protection schemes in power systems.	Understand

iv) **SYLLABUS**

Need for protective systems, Zones of protection, Current transformers and voltage transformers, Principle of operation of magneto optic CT/ PT.

Relays: Over current relays, Differential relays, Distance relays.

Protection of Transmission Line Systems, Use of line carrier and communication links, Effect of power swings on the performance of distance relays.

Protection of Bus-bar, Transformer and Generator & Motor Systems, Types of faults, High impedance and low impedance differential protection schemes, harmonic restraint relay, Restricted Earth Fault Protection, frame leakage protection.

Pilot relaying schemes: Pilot wire protection, carrier current protection.

Protection Scheme for Distribution Systems, Fundamentals of travelling wave protection scheme.

Digital Relays, Signal Conditioning Subsystems, Signal processing techniques, Digital filters, Decision making in Protective Relays, Wide Area Protection and Measurement.

v) (a) TEXT BOOKS

1) A. T. Johns and S. K. Salman, "Digital Protection for Power Systems," Peter Peregrinus Ltd, UK, 1995.
2) Waldemar Rebizant, "Digital Signal Processing in Power System Protection and Control", Springer Publication, 2013.
3) J. L. Blackburn, "Applied Protective Relaying," Westinghouse Electric Corporation, New York, 1982.

(b) REFERENCES

1) A. G. Phadke and J. S. Thorp, "Computer Relaying for Power Systems," Research study press Ltd, John Wiley & Sons, Taunton, UK, 1988.
2) S.P Patra, S.K Bl, lsu and S. Choudhary, "Power System Protection", Oxford IBH Pub.
3) S. Ravindernath and M. Chander, "Power System Protection and Switchgear", 2nd Edition, New Age International Publishers, 2018.
4) Badri Ram and Vishwakarma, "Power System Protection and Switchgear", 2nd Edition, McGraw Hill Education, 2017.
5) Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski, "Digital Signal Processing in Power System Protection and Control", Springer, 2011.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction:** Need for protective systems, Zones of protection, Current transformers and voltage transformers (Electromagnetic and Capacitive voltage transformers), Principle of operation of magneto optic CT/ PT, effect on relaying philosophy. **Relays:** Over current relays - time-current characteristics of over current relays: definite time over current relays, inverse Definite Minimum time - directional over current relays, current setting and time setting - Numerical Problems - Differential relays: Operating and restraining characteristics, types of differential relays, Distance relays: impedance relays, reactance relays, mho relays, quadrilateral relays, elliptical relays (basic principles and characteristics only).	9
II	**Protection of Transmission Line Systems:** Schemes of distance protection, Differential line protection, Phase comparison line protection, Use of line carrier and communication links, Effect of power swings on the performance of distance relays.	9

	Protection of Bus-bar, Transformer and Generator & Motor Systems*:* Types of faults, differential protection: High impedance and low impedance differential protection schemes, harmonic restraint relay, Restricted Earth Fault Protection, frame leakage protection, stator and rotor protection against various types of faults. **Pilot relaying schemes:** Pilot wire protection, carrier current protection (Basic Principles and schematic). **Protection Scheme for Distribution Systems:** Protection criteria for distribution system, Features of directional and non-directional protection schemes for distribution system, Fundamentals of travelling wave protection scheme.	
III	**Introduction to Digital (Numerical) Relays**- Basic Components of numerical Relays with block diagram, Processing Unit, Human machine Interface, Principle of operation- Comparison of numerical relays with electromechanical and static relays, Advantages of numerical relays - communication in protective relays (IEC 61850), Information handling with substation automation system (SAS). **Signal Conditioning Subsystems**: Surge Protection Circuits, Anti-aliasing filter, Conversion Subsystem, The Sampling Theorem, aliasing, Sample and Hold Circuit, Concept of analog to digital and digital to analog conversion, Idea of sliding window concept, Fourier, Discrete and fast Fourier transforms.	**9**
IV	**Signal processing techniques**: Sinusoidal wave based algorithms, Fourier Analysis based algorithms (half cycle and full cycle), Least squares based algorithm. **Digital filters –** Fundamentals of Infinite Impulse Response Filters, Finite Impulse Response filters, Filters with sine and cosine windows.	**9**
V	**Decision making in Protective Relays –** Deterministic decision making, Statistical Hypothesis testing, Decision making with multiple criteria, Adaptive decision schemes. **Wide Area Protection and Measurement**: Phasor Measurement Units, concept of synchronized sampling, Definition of wide-area protection, Architectures of wide-area protection, concept of Adaptive relaying, advantages of adaptive relaying and its application, Adaptive Differential protective scheme.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE0U41A	CONTROL SYSTEMS ENGINEERING	OEC	2	1	0	3	2020

i) **PRE-REQUISITE:** MA0U10B: Vector Calculus, Differential Equations and Transforms.

ii) **COURSE OVERVIEW**: This course introduces fundamental concepts in control theory to the students to enable them to model various components a control system using transfer function and state space model. The course also presents the concept of time response and frequency response of the systems. This course discusses the stability analysis of systems using different time domain and frequency domain methods. It thus helps the students to get an overview of the basic concepts in control systems and enables them to apply these control principles in various areas of industry.

iii) **COURSE OUTCOMES**

After the completion of the course, the student will be able to:

CO1	Develop a mathematical model of various electromechanical systems.	Apply
CO2	Apply Laplace transform method to obtain the time response of various control systems.	Apply
CO3	Apply Laplace transform method to obtain the frequency response of various control systems.	Apply
CO4	Use time domain techniques to analyse the stability of a system.	Apply
CO5	Use frequency domain techniques to analyse the stability of a system.	Apply

iv) **SYLLABUS**

Open loop-and closed loop control systems, Transfer function of LTI systems - Mechanical and Electromechanical systems – Introduction to state space model and concept of states (second order system only) - Force voltage and force current analogy - block diagram representation - signal flow graph - Mason's gain formula.

Time domain analysis of control systems: Transient and steady state responses - time domain specifications - first and second order systems - step responses of first and second order systems.

Error Analysis and Stability: Error analysis: Steady state error analysis and error constants - Dynamic error coefficients, Concept of BIBO stability and Asymptotic stability - Time response for various pole locations - stability of feedback systems - Routh's stability criterion.

Root locus technique: Construction of Root locus - stability analysis - effect of addition of poles and zeroes.

Frequency Domain Analysis: Frequency domain specifications - correlation between time domain and frequency domain responses, Polar plot, Bode Plot, Nyquist stability criterion.

v) (a) TEXT BOOKS

1) Nagarath I. J. and Gopal M., "Control System Engineering", 5th Edition, New Age International Publishers.
2) Ogata K, "Modern Control Engineering", 5th Edition, Prentice Hall, 2010.
3) Nise N. S, "Control Systems Engineering", 6th Edition, Wiley, 2010.
4) R. C. Dorf and Bishop R. H, "Modern Control Systems", 12th Edition, Prentice Hall, 2011.

(b) REFERENCES

1) Kuo B. C, "Automatic Control Systems", 7th Edition, Prentice Hall Inc., 1995.
2) Desai M. D., "Control System Components", Prentice Hall of India, 2008
3) Gopal M., "Control Systems: Principles and Design", 4th Edition, McGraw Hill Education, 2012.
4) Imthias Ahamed T. P, "Control Systems", Phasor Books, 2016.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Feedback Control Systems**: Terminology and basic structure of Open loop and Closed loop control systems - Examples of Automatic control systems (block diagram representations only). Transfer function approach to feed back control systems - Mechanical and Electromechanical systems: Force – voltage, force–current analogy. Introduction to state model and state concept (second order system only), Block Diagram Reduction Techniques. Signal flow graph - Mason's gain formula, Characteristic Equation.	**10**
II	**Performance Analysis of Control Systems:** Time domain analysis of control systems: Transient and steady state responses- Impulse and Step responses of first and second order systems Time domain specifications.	**12**
III	**Error analysis and Stability:** Error analysis: Steady state error analysis - static error coefficient of Type 0, 1, 2 systems. Dynamic error coefficients. Stability Analysis: Concept of stability - BIBO stability and Asymptotic stability - Time response for various pole locations - stability of feedback systems. Application of Routh's stability criterion to control system analysis - Relative stability.	**7**

IV	**Root Locus Technique:** Root locus technique: General rules for constructing Root loci – stability from root loci - Effect of addition of poles and zeros on Root locus.	**7**
V	**Frequency domain analysis**: Frequency domain specifications - correlation between time domain and frequency domain response. Polar plot: Concepts of gain margin and phase margin - stability analysis. Bode Plot: Construction of Bode plots - gain margin and phase margin - Stability analysis based on Bode plot. Nyquist stability criterion (criterion only).	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE0U41B	INTRODUCTION TO POWER PROCESSING	OEC	2	1	0	3	2020

i) **PRE-REQUISITE:** MA0U10B: Vector Calculus, Differential Equation and Transforms, ES0U10D: Basics of Electrical and Electronics Engineering.

ii) **COURSE OVERVIEW**: The goal of this course is to enhance the problem-solving skills by using various techniques to solve different types of AC and DC circuits. Time Domain analysis will help students to understand the transient and the steady-state response of R, L, C circuits. The course also aims to introduce two port network modelling and network functions.

iii) **COURSE OUTCOMES**

After the completion of the course, the student will be able to:

CO1	Explain different elements of power electronics.	Understand
CO2	Explain various power electronic converters.	Understand
CO3	Explain the basic principles of AC and DC motor drives.	Understand
CO4	Explain the structure of power processing systems in power supplies, renewable energy conversion and EVs.	Understand

iv) **SYLLABUS**

Introduction to power processing, elements of power electronics, power semiconductor devices. Uncontrolled, Semi controlled and fully controlled switches: Diode, SCR, MOSFETs and IGBTs, Advantages of wide bandgap devices - SiC, GaN.

Controlled rectifiers: Single- phase fully controlled SCR based bridge rectifier with R and RL load, DC-DC Converters: Buck, Boost and Buck-Boost converter.

Single phase half and full bridge Inverter: Square-wave operation with R load, Types of PWM - single pulse, multiple pulse and sinusoidal PWM, Total Harmonic Distortion (THD), Three phase voltage source inverter with R load - 120 degree and 180 degree conduction mode, Single phase AC voltage controller with R load.

Applications: Motor drives, Renewable energy, Power supplies, Electric vehicles.

v) (a) **TEXT BOOKS**

1) Ned Mohan, Tore M Undeland, William P Robbins, “Power electronics converters applications and design”, John Wiley and Sons, 2003.
2) Muhammad H. Rashid, “Power Electronics Circuits, Devices and Applications”, Pearson Education, 2009.
3) P.S. Bimbhra, “Power Electronics”, Khanna Publishers, New Delhi, 2012.

(b) REFERENCES

1) Dubey G. K. "Fundamentals of Electrical drives", Narosa Publishing House, 1995.
2) Andrzej M. Trzynadlowski, "Introduction to Modern Power Electronics", 3rd Edition, Wiley, 2015.
3) Iqbal Hussein, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press, 2003.
4) Abbasi S. A. and N. Abbasi, "Renewable Energy Sources and their Environmental Impact", Prentice Hall of India, 2001.
5) Sawhney G. S., "Non-Conventional Energy Resources", PHI Learning, 2012.
6) "Non-conventional energy sources", NPTEL lecture by Prof. Prathap Haridoss, IIT Chennai.
7) Abad, Gonzalo, "Power electronics and electric drives for traction applications", USA: Wiley, 2017.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to power processing, elements of power electronics, power semiconductor devices, Uncontrolled, Semi controlled and Fully controlled switches: Diode, SCR, MOSFETs and IGBTs- principle of operation. Advantages of wide bandgap devices - SiC, GaN.	**9**
II	Basic power conversion circuits - converter circuits: Controlled rectifiers: Single-phase fully controlled SCR based bridge rectifier with R and RL load (continuous mode only). Principle of operation and waveforms (No analysis required). DC-DC Converters (Non-isolated): Buck, Boost and Buck-Boost converter. Circuit operation, voltage gain and waveforms in continuous conduction mode (No analysis required).	**9**
III	Single phase half and full bridge Inverter: Square-wave operation with R load. Types of PWM - single pulse, multiple pulse and sinusoidal PWM. Total Harmonic Distortion (THD). Three phase voltage source inverter with R load - 120 degree and 180 degree conduction mode – waveforms. Single phase AC voltage controller with R load- waveforms.	**9**
IV	Applications - Motor drives: Introduction to electric motor drive - Block diagram, 4-quadrant operation of a separately excited dc motor (circuit diagram and waveforms only). Induction motor drives: Principle of operation - v/f control.	**9**

V	Applications 2: Renewable energy- solar PV installations-off grid and on grid systems: Principle of operation - Block diagram. Applications 3: Power supplies - Principle of operation of linear and switched mode power supply- requirements of power supplies- Isolation, protection and regulation. Applications 4: Electric vehicles - Introduction to HEV, PHEV and BEV-Block schematic of power train. Introduction to energy storage in EVs - Li Batteries, Hydrogen Fuel Cell.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE0U41C	RENEWABLE ENERGY SYSTEMS	OEC	3	0	0	3	2020

i) **PRE-REQUISITE: Students who have taken EE0M30B MINOR are not eligible to take this course**.

ii) **COURSE OVERVIEW**: The goal of this course is to expose the students to learn the concepts of solar thermal and solar electric systems. It illustrates the operating principles of wind, and ocean energy conversion systems and the features of biomass and small hydro energy resources. The course describes the concepts of fuel cell and hydrogen energy technologies.

iii) **COURSE OUTCOMES**

After the completion of the course, the student will be able to:

CO1	Illustrate the use of various renewable energy-based power generation scheme.	Understand
CO2	Explain the concepts of solar thermal and solar electric systems.	Understand
CO3	Illustrate the operating principles of wind, and ocean energy conversion systems.	Understand
CO4	Outline the features of biomass and small hydro energy resources.	Understand
CO5	Describe the concepts of fuel cell and hydrogen energy technologies.	Understand

iv) **SYLLABUS**

Introduction, Classification of Energy Resources- Conventional Energy Resources and Non-Conventional Energy Resources.

Principle of Conversion of Solar Radiation into Heat – Solar thermal collectors. – Flat plate collectors. Solar concentrators Solar Thermal Electric Power Generation, Solar Photovoltaic – Solar Cell fundamentals

Solar PV Systems – stand-alone and grid connected- Applications. Ocean Thermal Energy Conversion, Open Cycle (Claude cycle), Closed Cycle

Site-selection criteria- Biofouling - Wind Energy Conversion Systems wind speed measurement-Classification of WECS- types of rotors. wind power equation -Betz limit.

Electrical Power Output and Capacity Factor of WECS -Environmental impacts. Small Hydro Power - Classification as micro, mini and small hydro projects. Basic concepts and types of turbines- selection considerations.

Fuel Cell-principle of operation- Hydrogen energy - hydrogen production, electrolysis - thermo chemical methods - hydrogen storage and utilization.

v) (a) TEXT BOOKS

1) G. D. Rai, "Non-Conventional Energy Sources", Khanna Publishers, 2010.
2) Rao S. and B. B. Parulekar, "Energy Technology", Khanna Publishers, 1999.

(b) REFERENCES

1) G.N. Tiwari, "Solar Energy-Fundamentals, Design, Modelling and Applications", Narosa Publishers, 2002.
2) Earnest J. and T. Wizelius, "Wind Power Plants and Project Development", PHI Learning, 2011.
3) Sab S. L., "Renewable and Novel Energy Sources", MI. Publications, 1995.
4) Sawhney G. S., "Non-Conventional Energy Resources", PHI Learning, 2012.
5) Tiwari G. N., "Solar Energy- Fundamentals, Design, Modelling and Applications", CRC Press, 2002.
6) A.A.M. Saigh (Ed), "Solar Energy Engineering", Academic Press, 1977
7) Abbasi S. A. and N. Abbasi, "Renewable Energy Sources and Their Environmental Impact", Prentice Hall of India, 2001.
8) Boyle G. (ed.), "Renewable Energy - Power for Sustainable Future", Oxford University Press, 1996
9) Earnest J. and T. Wizelius, "Wind Power Plants and Project Development", PHI Learning, 2011.
10) F. Kreith and J.F. Kreider: "Principles of Solar Engineering", McGraw Hill, 1978.
11) Khan B.H, "Non-Conventional Energy resources", Tata McGraw Hill, 2009.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Introduction, Classification of Energy Resources- Conventional Energy Resources - Availability and their limitations- Non-Conventional Energy Resources – Classification, Advantages, Limitations; Comparison. SOLAR THERMAL SYSTEMS- Principle of Conversion of Solar Radiation into Heat – Solar thermal collectors. – Flat plate collectors. Solar concentrators (parabolic trough, parabolic dish, Central Tower Collector). SOLAR ELECTRIC SYSTEMS - Solar Thermal Electric Power Generation – Solar Photovoltaic – Solar Cell fundamentals - characteristics, classification, construction. Solar PV Systems – stand-alone and grid connected - Applications.	11

II	ENERGY FROM OCEAN - Ocean Thermal Energy Conversion (OTEC)- Principle of OTEC system - Open Cycle (Claude cycle), Closed Cycle (Anderson cycle) and Hybrid cycle. Site-selection criteria- Biofouling - Advantages & Limitations of OTEC. TIDAL ENERGY – Principle of Tidal Power- Components of Tidal Power Plant (TPP)- Classification-single basin - double basin types – Limitations - Environmental impacts.	**10**
III	WIND ENERGY – Introduction - Basic principles of Wind Energy Conversion Systems (WECS) wind speed measurement-Classification of WECS - types of rotors. wind power equation - Betz limit. Electrical Power Output and Capacity Factor of WECS- Advantages and Disadvantages of WECS -site selection criteria.	**9**
IV	BIOMASS ENERGY – Introduction - Biomass fuels - Biomass conversion technologies - Urban waste to Energy Conversion- Biomass Gasification - Biomass to Ethanol Production- Biogas production from waste biomass - factors affecting biogas generation- types of biogas plants – KVIC and Janata model - Biomass program in India.	**8**
V	SMALL HYDRO POWER- Classification as micro, mini and small hydro projects - Basic concepts and types of turbines- selection considerations. EMERGING TECHNOLOGIES: Fuel Cell-principle of operation – classification- conversion efficiency and losses - applications. Hydrogen energy - hydrogen production - electrolysis - thermo chemical methods - hydrogen storage and utilization.	**7**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE0U41D	ELECTRIC VEHICLES	OEC	2	1	0	3	2020

i) PRE-REQUISITE: Nil

ii) COURSE OVERVIEW: The main goal of this course is to expose the students to the fundamental concepts and trends in electric and hybrid vehicles. It gives an insight into the drive system, battery management system and energy sources used in electric vehicles. It also intends to deliver various communication protocols.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Explain the basic concepts of Electric and Hybrid Electric Vehicles.	Understand
CO2	Compare various configurations of Electric and Hybrid Electric drive trains based on application	Understand
CO3	Explain the propulsion unit for electric and hybrid vehicles.	Understand
CO4	Compare proper energy storage systems for vehicle applications.	Understand
CO5	Compare various communication protocols and technologies used in vehicle networks.	Understand

iv) SYLLABUS

Conventional Vehicles, Basics of vehicle performance, Basic Architecture of hybrid traction, Power flow control.

Electric Propulsion unit, Configuration and control of DC motor drives, Induction Motor drives.

Energy Storage Requirements in Hybrid and Electric Vehicles, Battery, fuel cell, flywheel and supercapacitor-based energy storage.

Design of electric and hybrid electric vehicle, sizing of components.

Communication Systems, Energy Management Strategies, EV charging technologies and policies.

v) (a) TEXT BOOKS

1) Iqbal Husain, “Electric and Hybrid vehicles: Design Fundamentals”, CRC press, 3rd Edition, 2021.
2) Ehsani M., “Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design”, CRC Press, 2005.
3) GianfranCOPistoia, “Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market”, Elsevier, 2010.

4) Chan C. C. and Chau K. T., "Modern Electric Vehicle Technology", Oxford University Press, 2001.

(b) REFERENCES

1) James Larminie, John Lowry, "Electric Vehicle Technology Explained", 2nd Edition Wiley 2003.
2) Fuhs A. E., "Hybrid Vehicles and the Future of Personal Transportation", CRC Press, 2009.
3) Chris Mi, Abul Masrur M., "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives", 2nd Edition, John Wiley & Sons Ltd, 2017.
4) Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 2013.

(c) ONLINE RESOURCES

1) NPTEL courses/Materials (IITG, IITM,IITD) – Electric and Hybrid vehicles
   https://nptel.ac.in/courses/108/103/108103009/ (IIT Guwahati)
   https://nptel.ac.in/courses/108/102/108102121/ (IIT Delhi)
   https://nptel.ac.in/courses/108/106/108106170/ (IIT Madras)
2) FOC Control - video lecture by Texas Instruments
   https://training.ti.com/kr/field-oriented-control-permanent-magnet-motors
3) Sensored and sensorless FOC control of PMSM motors – Application notes (TI, MATLAB)
   https://www.ti.com/lit/an/sprabz0/sprabz0.pdf?ts=1620018267996&ref_url=https%253A%252F%252Fwww.google.com%252F
   https://in.mathworks.com/help/physmod/sps/ref/pmsmfieldorientedcontrol.html
4) Electric Vehicle Conductive AC Charging System
   https://dhi.nic.in/writereaddata/UploadFile/REPORT%20OF%20COMMITTEE636469551875975520.pdf
   Electric Vehicle Conductive AC Charging System

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to Hybrid Electric Vehicles**: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles. **Basics of vehicle performance**, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.	9

II	**Hybrid Electric Drive-trains**: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies. **Electric Drive-trains:** Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies.	**9**
III	**Electric Propulsion unit:** Introduction to electric components used in hybrid and electric vehicles. Configuration and control of separately excited DC motors, Induction Motors (block diagram representation of FOC).	**9**
IV	**Energy Storage**: Introduction to energy storage requirements in Hybrid and Electric Vehicles- Battery based energy storage systems - Fuel Cell based energy storage systems- Introduction to Supercapacitors and Hydrogen energy storage - Hybridization of different energy storage devices. **Types of charging stations** - AC Level 1 & 2, DC - Level 3 –V2G concept.	**10**
V	**Communications**, supporting subsystems: In vehicle networks- Communication Protocols - CAN, LIN, FLEXRAY (Basics only). **Introduction to energy management strategies**: Classification of different energy management strategies, comparison of different energy management strategies.	**8**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE0U41E	ENERGY MANAGEMENT	OEC	3	0	0	3	2020

i) PRE-REQUISITE: Nil

ii) COURSE OVERVIEW: This course is to expose the students to the fundamental concepts of energy management and auditing.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Explain the significance and procedure for energy management and audit.	Understand
CO2	Apply energy efficiency opportunities and management for electrical loads.	Apply
CO3	Explain the energy efficiency improvement in boilers and furnaces.	Understand
CO4	Identify the energy management opportunities in HVAC systems	Apply
CO5	Develop the economic feasibility of the energy conservation measures.	Apply

iv) SYLLABUS

Energy Management - Energy Audit- Instruments for energy audit, Energy audit report - Power quality audit, Energy conservation in buildings.

Energy management in Electricity Utilization, Types of industrial loads, Peak demand controls and methodologies. Energy management in boilers and furnaces, Properties of steam.

General fuel economy measures in furnaces - Draft control.

Energy management in HVAC systems - Coefficient of performance, Capacity, Factors affecting Refrigeration and Air conditioning system performance and savings opportunities.

Waste Heat Recovery system, Cogeneration, Computer aided energy management.

Economic analysis methods - cash flow model, time value of money, evaluation of proposals, pay-back method, average rate of return method, internal rate of return method, present value method, life cycle costing approach.

v) (a) TEXT BOOKS

1) Albert Thumann, William J. Younger, “Handbook of Energy Audits”, CRC Press, 2003.
2) Charles M. Gottschalk, “Industrial Energy Conservation”, John Wiley & Sons, 1996.

3) Craig B. Smith, Kelly E. Parmenter, "Energy Management Principles", 2nd Edition, Elsevier, 2015.

(b) REFERENCES

1) D. Yogi Goswami, Frank Kreith, "Energy Management and Conservation Handbook", CRC Press, 2007.
2) G.G. Rajan, "Optimizing energy efficiencies in industry", Tata McGraw Hill, Pub. Co., 2001.
3) IEEE recommended practice for energy management in industrial and commercial facilities, IEEE std 739 -1995 (Bronze book).
4) M Jayaraju and Premlet, "Introduction to Energy Conservation and Management", Phasor Books, 2008.
5) Paul O'Callaghan, "Energy management", McGraw Hill Book Co., 1993.
6) Wayne C. Turner, "Energy management Hand Book", The Fairmount Press Inc., 1997.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Energy Management - General Principles and Planning:** General principles of energy management and energy management planning. **Energy Audit:** Definition, need, types and methodologies. Instruments for energy audit, Energy audit report - Power quality audit. Energy conservation in buildings: ECBC code (basic aspects), Building Management System (BMS).	9
II	**Energy management in Electricity Utilization:** Energy management opportunities in Lighting, pumps, fans, compressors and Motors, Electrolytic Process and Electric heating. Types of industrial loads. Peak demand controls and methodologies,	9
III	**Energy management in boilers and furnaces:** Types of boilers, Combustion in boilers, Performances evaluation, Feed water treatment, Blow down, Energy conservation opportunities in boiler. Properties of steam, Assessment of steam distribution losses, Steam leakages, Steam trapping, Condensate and flash steam recovery system, Identifying opportunities for energy savings. Classification, General fuel economy measures in furnaces, Excess air, Heat Distribution, Temperature control, Draft control.	9
IV	**Energy management in HVAC systems:** HVAC system: Coefficient of performance, Capacity, Factors affecting Refrigeration and Air conditioning system performance and savings opportunities.	9

	Classification and Advantages of Waste Heat Recovery system, analysis of waste heat recovery for Energy saving opportunities. Cogeneration - Types and Schemes, Optimal operation of cogeneration plants - Case study. Computer aided energy management.	
V	**Energy Economics:** Economic analysis methods-cash flow model, time value of money, evaluation of proposals, pay-back method, average rate of return method, internal rate of return method, present value method, life cycle costing approach, Case studies.	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance : 10 marks

CA Exams (2 numbers) : 25 marks

Assignment/Project/Case study etc. : 15 marks

Total : **50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
NC0U40A	INDUSTRIAL SAFETY ENGINEERING	MNC	2	1	0	-	2020

i) PRE-REQUISITE: Nil

ii) COURSE OVERVIEW: The course is intended to give knowledge of various safety management principles, various safety systems, various machine guarding devices, hazard identification techniques, energy sources, systems & applications and the need in the present context. Learners will be able to compare different hazard identification tools and choose the most appropriate based on the nature of industry. It aims to equip students in working with projects and to take up research work in connected areas.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Explain the theories of accident causation and preventive measures of industrial accidents.	Understand
CO2	Explain about personal protective equipment, its selection, safety performance & indicators and importance of housekeeping.	Understand
CO3	Explain different issues in construction industries.	Understand
CO4	Summarize various hazards associated with different machines and mechanical material handling.	Understand
CO5	Utilize different hazard identification tools in different industries with the knowledge of different types of chemical hazards	Apply

iv) SYLLABUS

Introduction to Industrial safety Engineering- Theories of accident causation- Role of management, supervisors, workmen, unions, government and voluntary agencies in safety- Safety committee and safety organisation.

Personal protection in the work environment - Standards related to PPEs- Monitoring Safety Performance – Housekeeping - Work permit system.

Introduction to construction industry and safety – Excavation - Tunnelling - Blasting- Familiarization with relevant Indian Standards and the National Building Code provisions on construction safety - Relevance of ergonomics in construction safety.

Machinery safeguard – Types of guards and devices - Safety in Power Presses, turning, boring, milling, planning and grinding- Welding and Cutting - Material Handling - Handling assessments and techniques.

Hazard identification - Types of hazards - Types of Fire extinguishers fire - The Dow Fire and Explosion Hazard Index - HAZOP- Chemical hazard - Material Safety Data Sheets.

v) (a) TEXT BOOKS

1) R.K Jain, "Industrial Safety: Health and Environment management systems", Khanna Publications, 2000.
2) Paul S V, "Safety management System and Documentation training Programme Handbook", CBS Publication 2000.
3) Krishnan N.V, "Safety management in Industry", JaiCO Publishing House, New Delhi, 1997.
4) John V. Grimaldi and Rollin H. Simonds, "Safety management", All India Traveller Book Seller, Delhi, 1989.

(b) REFERENCES

1) Ronald P. Blake, "Industrial safety", Prentice Hall, New Delhi, 1973.
2) Alan Waring, "Safety management system", Chapman & Hall, England, 1996.
3) Vaid K.N., "Construction safety management", National Institute of Construction Management and Research, Mumbai, 1988.
4) AIChE/CCPS, "Guidelines for Hazard Evaluation Procedures", (2nd Edition), Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York. 1992.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Safety introduction**- Need for safety, Safety and productivity. Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable accidents. Theories of accident causation. Safety organization- objectives, types, functions, Role of management, supervisors, workmen, unions, government and voluntary agencies in safety. Safety policy. Safety Officer-responsibilities, authority. Safety committee-need, types, advantages.	9
II	**Personal protection in the work environment**- Types of PPEs, Personal protective equipment- respiratory and non-respiratory equipment. Standards related to PPEs. **Monitoring Safety Performance**: Frequency rate, severity rate, incidence rate, activity rate. **Housekeeping**: Responsibility of management and employees. Advantages of good housekeeping. 5 s of housekeeping. **Work permit system**- objectives, hot work and cold work permits. Typical industrial models and methodology. Entry into confined space.	9
III	**Introduction to construction industry and safety issues in construction**: Safety in various construction operations –	9

	Excavation and filling – Under-water works – Under-pinning & Shoring – Ladders & Scaffolds – Tunneling – Blasting – Demolition – Confined space – Temporary Structures. Familiarization with relevant Indian Standards and the National Building Code provisions on construction safety. **Relevance of ergonomics in construction safety**- Ergonomics Hazards - Musculoskeletal Disorders and Cumulative Trauma Disorders.	
IV	**Machinery safeguard**-Point-of-Operation, Principle of machine guarding -types of guards and devices. Safety in turning, and grinding. Welding and Cutting-Safety, Precautions of Gas welding and Arc Welding. **Material Handling**-Classification-safety consideration- manual and mechanical handling. Handling assessments and techniques- lifting, carrying, pulling, pushing, palletizing and stocking. Material Handling equipment-operation & maintenance. Maintenance of common elements-wire rope, chains, slings, hooks, clamps. Hearing Conservation Program in Production industries.	**9**
V	**Hazard identification and analysis:** Hazard and risk, Types of hazards –Classification of Fire, Types of Fire extinguishers, fire explosion and toxic gas release, Structure of hazard identification and risk assessment. Identification of hazards: Inventory analysis, Fire and explosion hazard rating of process plants - The Dow Fire and Explosion Hazard Index, Preliminary hazard analysis, Hazard and Operability study (HAZOP)) – methodology, criticality analysis, corrective action and follow-up. Control of Chemical Hazards, Hazardous properties of chemicals, Material Safety Data Sheets (MSDS)	**9**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U48A	CONTROL SYSTEMS LAB	PCC	0	0	3	2	2020

i) PRE-REQUISITE: EE1U30E: Linear Control Systems, EE1U40A: Advanced Control Theory.

ii) COURSE OVERVIEW: Objective of the course is to impart practical experience to students to develop mathematical models for electrical systems. The course deals with the time and frequency analysis of the systems and implementation of compensators for systems based on system performance. The course is also designed to familiarise the students with different simulation tools used in control engineering.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Develop the mathematical model of a given physical system by conducting appropriate experiments	Apply
CO2	Analyse the performance of second order systems in time domain and frequency domain.	Analyse
CO3	Analyse the performance of different process control systems	Analyse
CO4	Analyse the performance of different types of controllers	Analyse
CO5	Simulate and analyse various control system models and compensators using MATLAB/SIMULINK tools.	Analyse

iv) SYLLABUS

Modeling of Transfer function of AC Servomotor and DC Servomotor – 3 sessions.

Time and frequency responses of second order systems – 2 sessions.

Frequency response characteristics of Lag networks and Lead networks – 2 sessions.

Study of P, PI and PID controllers and various types of Synchros – 1 session.

Study of performance characteristics of a typical Level control system and inverted pendulum – 2 sessions.

Experiments on MATLAB Software and PLC – 5 sessions.

v) REFERENCES

1) Ogata K., Modern Control Engineering, Pearson Prentice Hall, 2006.
2) Gopal M., Control Systems, Tata McGraw-Hill, 3rd Edition, 2006.

3) Franklin G. F., Powell J. D. and Naeini A. E., Feedback Control of Dynamic Systems, Pearson Education Asia, 7th Edition., 2014.
4) Goodwin G. C., Graebe S. F. and Salgado M. E., Control System Design, Prentice Hall India, 2003.
5) D'Azzo J. J., Houpis C. H., Sheldon S. N., Linear Control System Analysis & Design with MATLAB, 5th Edition, Marcel Dekker, 2003.

vi) COURSE PLAN

Expt. No.	List of Experiments	No. of hours
I	**Step response of a second order system** Objective: Design a second order system (eg: RLC network) to analyse the following: A. The effect of damping factor (ξ: 0, <1, =1, >1) on the unit step response using simulation study (M-File and SIMULINK). B. Verification of the delay time, rise time, peak overshoot and settling time with the theoretical values. C. Performance analysis of hardware setup and comparison with the simulation results.	**3**
II	**Performance Analysis using Root-Locus Method** Objective: Plot the root locus of the given transfer function to analyse the following using simulation: A. Verification of the critical gain, with the theoretical values. B. The effect of the controller gains K on the stability. C. The sensitivity analysis by giving small perturbations in given poles and zeros. D. The effect of the addition of poles and zeros on the given system.	**3**
III	**Stability Analysis by Frequency Response Methods.** Objective: Plot the i) Bode plot and ii) Nyquist plot of the given transfer functions to analyse the following using simulation: A. Determination of Gain Margin and Phase Margin. B. Verification of GM and PM with theoretical values. C. The effect of the controller gains K on the stability. D. The effect of the addition of poles and zeros on the given system (especially the poles at origin).	**3**
IV	**Realisation of lead compensator.** Objective: Design, set up and analyse the gain and phase plots of a lead compensator by hardware experimentation using i) passive elements and ii) active components.	**3**
V	**Realisation of lag compensator.** Objective: Design, set up and analyse the gain and phase plots of a lag compensator by hardware experimentation using i) passive elements and ii) active components.	**3**
VI	**Design of compensator in frequency domain and time domain.**	**3**

	Objective: Design a compensator for the given system to satisfy the given specifications A. Time domain specifications using MATLAB. B. Frequency domain specifications using MATLAB.	
VII	**State space model for analysis and design** Objective: Study and analysis of state variable models of a given system (eg. DC Motor speed control/ Servo motor) and design a controller by pole-placement technique using MATLAB based tool boxes. A. Determine the open loop stability, controllability and observability. B. Analyse the effect of system parameters on eigen values and system performance. C. Design a controller by pole-placement technique.	**3**
VIII	**PID Controller Design** Objective: Design and analysis of a PID controller for a given system (eg. DC Motor speed control/Servo motor/etc.) using SIMULINK/ MATLAB based tool boxes A. Design of PID controller to meet the given specifications B. Study the effect of tuning of PID controller on the above system.	**3**
IX	**Phase plane analysis of nonlinear autonomous systems** Objective: Study and analysis of phase trajectory of a given nonlinear autonomous system using state space model in Simulation tools. A. Determination and verification of the singular points, B. Stability Analysis of the system at various singular points from phase portraits.	**3**
X	**Transfer Function of Armature and Field Controlled DC Motor** Objective: Obtain the transfer function of the armature and field-controlled DC motor by experiment.	**3**
XI	**Synchro Transmitter and Receiver.** Objective: Plot and study the different performance characteristics of Synchro transmitter- receiver units in Direct mode and Differential mode.	**3**
XII	**Transfer function of AC Servo motor.** Objective: Obtain the open loop transfer function of AC Servo motor by experiment.	**3**
XIII	**Performance of a typical process control system** Objective: Study of performance characteristics and response analysis of a typical temperature/Flow/ Level control system/PLC controller for lift mechanism.	**3**

XIV	**Closed loop performance of inverted pendulum.** Objective: Study of performance characteristics of inverted pendulum by experiment. A. Determine the various unknown parameters of an inverted pendulum experimentally, B. Obtain and analyse the non-linear and linearised models, C. Design and implement various state feedback controllers to analyse the performance of the system.	**3**
	Total hours	**45**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	15 marks
CA Exam (1 number)	:	30 marks
Assignment/Project/Case study etc.	:	30 marks
Total	:	**75 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	75	75	3 hours

ix) END SEMESTER EXAMINATION PATTERN

a)	Preliminary work	:	15 marks
b)	Implementing the work/Conducting the experiment	:	20 marks
c)	Performance, result and inference (usage of equipment and troubleshooting):	:	15 marks
d)	Viva voce	:	20 marks
e)	Record	:	5 marks
	Total	**:**	**75 marks**

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U49A	SEMINAR	PWS	0	0	3	2	2020

i) COURSE OVERVIEW: The goal of Seminar is to develop skills in the students to conduct literature survey, to update latest developments in their engineering disciplines, to prepare technical reports and to make effective presentations.

ii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Identify an engineering problem and propose a work plan to solve it.	Apply
CO2	Analyse a current topic of professional interest and present it before an audience.	Analyse
CO3	Identify promising new directions of various cutting-edge technologies.	Apply
CO4	Develop skills in presentation and discussion of research topics in a public forum and compile the detailed report unfolding results.	Apply

iii) GUIDELINES

Each student shall identify a topic of current relevance in his/her branch of engineering, get the approval of the topic and action plan from an identified guide, collect sufficient literature on the topic, study and analyse the material collected, prepare a technical report as per guidelines and get approval from the guide, make a presentation in the class. The topic of seminar should be based on research publications or patents in the branch of engineering concerned, or of interest to the engineering community as a whole. The research papers referred should be from a publication of repute or a conference of international level in the concerned area of engineering or published materials from reputed publishers and business houses.

iv) ASSESSMENT PATTERN

Presentation	: 40
Technical knowledge through Viva- voce	: 30
Assessment by seminar guide including report	: 20
Assessment by Seminar coordinator	: 10
Total marks	**: 100**

(The evaluation committee comprises HoD or a senior faculty member and Seminar coordinator).

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1U49B	PROJECT PHASE I	PWS	0	0	6	2	2020

i) PRE-REQUISITE: Identification of area of interest and basic subject knowledge.

ii) COURSE OVERVIEW: The goal of this course is to enable project identification and execution of preliminary works on final semester Project. It creates an urge in students to develop skills in doing literature survey, technical presentation and report preparation.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Utilize literature survey systematically.	Apply
CO2	Analyse the problems in the related area and identify current real-world issues.	Analyse
CO3	Develop professional ethics and communicate effectively.	Apply
CO4	Plan and work effectively as an individual and as a member or leader of a diverse team.	Apply

iv) GUIDELINES

1) Identify suitable projects relevant to the branch of study.
2) Form project team.
3) Identify a project supervisor.
4) In case of interdisciplinary projects, the faculty member(s) from the concerned department(s) are also the supervisor(s) for the students.
5) Present the project proposal before the assessment board (excluding the external expert) and get it approved by the board.
6) The preliminary work to be completed:
   a. Literature survey
   b. Formulation of objectives
   c. Formulation of hypothesis/design/methodology
   d. Formulation of work plan
   e. Conducting preliminary Analysis
   f. Seeking funds
   g. Preparation of preliminary report

Note: The same project should be continued in the eighth semester by the same project team.

v) ASSESSMENT PATTERN

Only Continuous Internal Evaluation (CIE), minimum required to pass is 50 marks.

The evaluation committee comprises HoD or a senior faculty member, Project coordinator and Project supervisor.

Project Supervisor	: 30
Interim evaluation by the evaluation Committee	: 20
Final Evaluation by the evaluation Committee	: 30
The report evaluated by the evaluation committee	: 20
Total marks	**: 100**

vi) EVALUATION BY GUIDE

The guide/supervisor must monitor the progress being carried out by the project groups on regular basis. In case it is found that progress is unsatisfactory, it should be reported to the Department Evaluation Committee for necessary action. The presence of each student in the group and their involvement in all stages of execution of the project shall be ensured by the guide.

Project evaluation by the guide: 30 marks

This mark shall be awarded to the students in his/her group by considering the following aspects.

i) **Topic selection: 2 marks**
Innovativeness, social relevance etc.

ii) **Problem definition: 2 marks**
Identification of the social, environmental and ethical issues of the project problem.

iii) **Purpose and need of the project: 3 marks**
Detailed and extensive explanation of the purpose and need of the project.

iv) **Project Objectives: 2 marks**
All objectives of the proposed work are well defined, Steps to be followed to solve the defined problem are clearly specified.

v) **Project Scheduling and Distribution of work among team members: 3 marks**
Detailed and extensive scheduling with timelines provided for each phase of project. Work breakdown structure well defined.

vi) **Literature Survey: 4 marks**
Outstanding investigation in all aspects.

vii) **Student's diary/Daily log: 7 marks**
The main purpose of writing daily diary is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the daily/weekly activity diary the day-to-day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches and drawings related to the observations made by the students. The daily/weekly activity diary shall be signed after every day/week by the guide.

viii) **Individual Contribution: 7 marks**
The contribution of each student at various stages.

EVALUATION RUBRICS PROJECT PHASE I: INTERIM EVALUAT					
Sl. No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**
PHASE 1 INTERIM EVALUATION (20 MARKS)					
1-a	Literature survey and Review (Group assessment) [CO1]	10	• The team has failed to come with a relevant topic. • The review of literature provides very little of the background information on the relevant topic. • No critical analysis or identification of gaps is carried out. • Most of the statements are quoted directly and the team tried to gather information as such without verifying the authenticity. • No literature review was properly conducted and no objectives formed so far.	• The team has identified a topic. • The review of literature provides some of the background information and needs to be revised. • Critical analysis of the literature is missing and suggestions were given to improve the relevance and to identify the gaps. • Relevant references were missing and there is no clear evidence to explain the topic identified. • Identified some objectives but not strong enough to explain it.	• The selection of topic i after brainstorming a evidences are documente • The review of lite appropriate and most b information is provided. • The relevant references w reviewed but there is improvement • Objectives identified w clarity but some objectiv be improved.
			(0 - 3 Marks)	(4 - 6 Marks)	(7 - 9 Marks)
1-b	Socio-environmental relevance/ Innovation/ Creativity (Group assessment) [CO2]	5	• The objective of the project has neither social nor environmental relevance. • The project does not involve elements of creativity and innovation.	• The objective of the project has least social or environmental relevance. • No major contributions in innovative aspects.	• The objective of the socially or enviro relevant. • The project involves som of creativity and innovati
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)

1-c	Project Planning, Scheduling and Resources/ Tasks Identification and allocation. (Group assessment) [CO2]	5	• No evidence of planning or scheduling of the project. • The students did not have any idea on what materials / resources to be used in the project. • The students do not have any awareness on the budget required.	• Some evidence of a primary plan. • Some ideas on the materials /resources required. • The students have some idea on the finances required and they have not formalized a budget plan. • Some indication on task allocation among the team members.	• Good evidence of plann Materials were listed an out, but needs improveme • Schedules prepared we detailed one. • Better task allocation am members.
			(0 -1 Marks)	(2 - 3 Marks)	(4 Marks)
Total – 20 marks					

EVALUATION RUBRICS PROJECT PHASE I: FINAL EVALUATION					
Sl. No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Go**
PHASE I FINAL EVALUATION (30 MARKS)					
1-d	Formulation of Design / Methodology and Progress (Group assessment) [CO2]	5	• Team members have no idea about the design and the methodology adopted. • Team has no progress after the evaluation. • Extensive support required from the project supervisor to achieve a satisfactory execution of various stages of the project.	• The students have some knowledge on the design procedure to be adopted, and the methodologies. • Not made much progress in the design. • Needs assistance at various stages of the project.	• The team is co with design adopted and h some progress. • The methodolo known to them extend. • Adherence to a and effective org activities. • Needs some assi faculty to arrive solutions to prob
			(0 -1 Marks)	(2-3 Marks)	(4 Mark

1-e	Individual and Teamwork Leadership (Individual assessment) [CO4]	10	• No active involvement in the project. • Quality of the work is uncertain. • The student does not show any interest in the project activities.	• The student shows some interest and participates in some of the activities. • Not a good team player. • Often listens to, shares with and sometimes supports the efforts of others.	• Provide suggestions betterment of the • Usually listens to keep people wo together as a tean • The student sh interest in projec up tasks and a complete them.
			(0 - 3 Marks)	(4 - 6 Marks)	(7 - 9 Mar
1-f	Preliminary Analysis/ Modeling / Simulation/ Experiment / Design/ Feasibility Study (Individual & group assessment). [CO3]	10	• The team has not done any preliminary work with respect to the project area. • Lacks of proper knowledge in the topic. • They need to improve a lot. • Less ability for self-learning.	• The team has started doing some preliminary work with respect to the project. • Finds difficult to answer complex questions related to the project work. • Limited knowledge about the modern tool used in the project.	• The team has amount of investigation • They can improv • Can handle questions with re • Adequate knowl modern tool us project.
			(0 - 3 Marks)	(4 - 6 Marks)	(7 - 9 Mar

1-g	Documentation and presentation/ Communication. (Individual & group assessment). [CO3]	5 –	• Presentation lacks clarity. • Student lack familiarity with the topic. • The individual student contributes only occasionally in the discussions. • The team did not document the work at all. • No weekly discussion with the faculty supervisor and poor maintenance of log book. • The presentation was light in content and dull in appearance.	• Slight difficulty in communicating the contents in English • Interaction with the guide is minimal. • Overall quality needs to be improved • Individual performance desires to be enhanced. • Performance is satisfactory.	• Presentation i structured and ap the audience. • Maintains a log most of the pro were documente improvement. • The individual p and performanc good.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks
Total – 30 marks					

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	EVALUATION RUBRICS_PROJECT PHASE I: REPORT EVALUATI				
Sl. No.	**Parameters**	**Marks**	**Poor**	**Fair**	**VERY GOOD**
	PHASE I FINAL EVALUATION (20 MARKS)				
1-h	Report [CO3]	20	• The prepared report is shallow and not as per standard format. • Lack of effort in preparation.	• Project report follows the standard format to some extent. • Language needs to be improved. • All references are not cited properly.	• Systematic documentation and is following the standard format. • Organization of the report is good. • Most of references are cited properly.
			(0 - 7 Marks)	(8 -12 Marks)	(14 - 19 Marks)

B.TECH S7 MINORS

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE0M49A	MINI PROJECT	VAC	0	0	3	4	2020

i) PRE-REQUISITE: Students who have taken Electrical Engineering MINOR course are eligible to take this course.

ii) COURSE OVERVIEW: A Project topic must be selected either from research literature or the students themselves may propose suitable topics in consultation with their guides. The object of Project Work I is to enable the student to take up investigative study in the broad field of Electrical and Electronics Engineering, either fully theoretical/practical or involving both theoretical and practical work to be assigned by the Department on a group of three/four students, under the guidance of a supervisor. This is expected to provide a good initiation for the student(s) in R&D work.

The assignment to normally include:

- Survey and study of published literature on the assigned topic.
- Preparing an Action Plan for conducting the investigation, including team work.
- Working out a preliminary Approach to the Problem relating to the assigned topic.
- Block level design documentation.
- Conducting preliminary Analysis / Modelling / Simulation / Experiment / Design / Feasibility.
- Preparing a Written Report on the Study conducted for presentation to the Department.

iii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Identify and synthesize problems and propose solutions to them.	Understand
CO2	Prepare work plan and liaison with the team in completing as per schedule.	Understand
CO3	Validate the above solutions by theoretical calculations and through experimental	Understand
CO4	Write technical reports and develop proper communication skills.	Understand
CO5	Present the data and defend ideas	Understand

iv) COURSE PLAN

In this course, each group consisting of three/four members is expected to design and develop a moderately complex software/hardware system with practical applications. This

should be a working model. The basic concept of product design may be taken into consideration. Students should identify a topic of interest in consultation with Faculty-in-charge of mini project /Advisor. Review the literature and gather information pertaining to the chosen topic. State the objectives and develop a methodology to achieve the objectives. Carryout the design/fabrication or develop codes/programs to achieve the objectives. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on a minimum of two reviews. The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The product has to be demonstrated for its full design specifications. Innovative design concepts, reliability considerations, aesthetics/ergonomic aspects taken care of in the project shall be given due weight.

v) CONTINUOUS ASSESSMENT EVALUATION PATTERN

The End Semester Evaluation (ESE) will be conducted as an internal evaluation based on the product, the report and a viva- voce examination, conducted by a 3-member committee appointed by Head of the Department comprising HoD or a senior faculty member, academic coordinator for that program and project guide/coordinator. The Committee will be evaluating the level of completion and demonstration of functionality/specifications, presentation, oral examination, working knowledge and involvement.

The Continuous Internal Evaluation (CIE) is conducted by evaluating the progress of the mini project through minimum of TWO reviews. At the time of the 1st review, students are supposed to propose a new system/design/idea, after completing a thorough literature study of the existing systems under their chosen area. In the 2nd review students are expected to highlight the implementation details of the proposed solution. The review committee should assess the extent to which the implementation reflects the proposed design. A well coded, assembled and completely functional product is the expected output at this stage. The final CIE mark is the average of 1st and 2nd review marks.

A zeroth review may be conducted before the beginning of the project to give a chance for the students to present their area of interest or problem domain or conduct open brain storming sessions for innovative ideas. Zeroth review will not be a part of the CIE evaluation process.

Continuous Internal Evaluation Pattern:

Attendance	: 10 marks
Marks awarded by Guide	: 15 marks
Project Report	: 10 marks
Evaluation by the Committee	: 40 Marks

End Semester Examination Pattern:

The following guidelines should be followed regarding award of marks.

(a) Demonstration	: 50 Marks
(b) Project report	: 10 Marks
(c) Viva voce	: 15marks

vi) MARK DISTRIBUTION

Total Marks	CIE	ESE
150	75	75

B.TECH S7 HONOURS

Group	Course Code	Course Name	L-T-P	Credits
I	EE1H40A	Operation and Control of Generators	4-0-0	4
II	EE1H40B	Dynamics of Power Converters	3-1-0	4
III	EE1H40C	Control and Dynamics of Microgrids	4-0-0	4
IV	EE1H40D	Smart Grid and interfacing	4-0-0	4

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1H40A	OPERATION AND CONTROL OF GENERATORS	VAC	4	0	0	4	2020

i) PRE-REQUISITE: EE1U20D: DC Machines and Transformers, EE1U30D:- Synchronous and Induction Machines.

ii) COURSE OVERVIEW:

The goal of this course is to expose the students to impart knowledge about the broad classification of various electric generator topologies and types of excitation systems. It also intends to deliver the operation and control strategies of induction generators, synchronous generators and Permanent Magnet Synchronous generators.

iii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO1	Compare the types of excitation systems and explain the need for Power System Stabilizer.	Understand
CO2	Explain the various active and reactive power control schemes of synchronous generators.	Understand
CO3	Develop the model of synchronous machine including the effect of saliency.	Apply
CO4	Illustrate the construction and principle of operation of Wound Rotor Induction generator and Self excited Induction generator.	Understand
CO5	Construct the model of Permanent Magnet Synchronous Generators.	Apply

iv) SYLLABUS

Electric generators-types, applications, review.

Excitation systems-block diagram, components, classification, compensation of excitation systems, IEEE type.

Control of active and reactive power-active power and frequency control, automatic generation control, reactive power and voltage control.

Synchronous machine dynamics-stability, swing equation.

Induction generators-operation at power grid, Self-excited induction generators.

Permanent magnet synchronous generators-field distribution, emf and torque, autonomous PMSG.

v) (a) TEXT BOOKS

1) Concordia C., Synchronous Machines, Wiley Publications, 1958.
2) Kimbark E. W., Power System Stability, Vol. III, Wiley Publications, 2017.

3) Kundur P., Power system stability and control, McGraw-Hill, 1994.
4) Stevenson W. D., Elements of Power system analysis, 1995.

(b) REFERENCES

1) Hadi Saddat, Power System Analysis, McGraw-Hill, 2002.
2) Fitzgerald A. E., Charles Kingsley Jr., Stephen D. Umans, Electric Machinery, McGraw-Hill Higher Education,6th Edition, 2003.
3) Bhag Singh Guru, Huseyin R. Hiziroglu, Electric Machinery and Transformers, Oxford University Press Inc, 3rd Edition,2000.
4) Bhimbra P. S., Generalized theory of electrical machines, Khanna Publishers, 7th Revised Edition 2002.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Electric Generators**- Types of electric generators, generator applications. **Excitation systems**-block diagram, classification-DC, AC and static systems, components-voltage regulator, power system stabilizer. Compensation of excitation systems-IEEE type excitation systems, instability problem of exciter, solution to the instability of exciter, need of the power system stabilizer. Co-ordinated AVR, PSS and speed governor control, FACTS added control of synchronous generators.	**12**
II	**Control of active power and reactive power**: Active power and frequency control-fundamentals of speed governing, control of generating unit power output, fundamentals of automatic generation control. Reactive power and voltage control-production and absorption of reactive power, methods of voltage control, shunt reactors, shunt capacitors, series capacitors, synchronous condensers, static VAR systems.	**12**
III	**Synchronous machine dynamics:** Basic dynamics of synchronous generators in transient situations, factors affecting transient stability, swing equation, models for stability studies, synchronous machine model including saliency, steady-state stability-small disturbances, transient stability-equal area criterion-application to sudden increase in power output.	**12**
IV	**Wound rotor induction generators**-construction elements, steady state equations, equivalent circuit, phasor diagrams, operation at the power grid- stator power versus power angle, rotor power versus power angle and operation at zero slip. **Self-excited induction generators**: cage rotor induction machine principle, self-excitation-a qualitative view, steady state performance of three phase SEIGs.	**13**

V	**Permanent magnet synchronous generator systems:** practical configuration and their characterization- air-gap field distribution, emf and torque, stator core loss modelling, circuit model, autonomous PMSGs with controlled constant speed and AC load.	**11**
	Total hours	**60**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1H40B	DYNAMICS OF POWER CONVERTERS	VAC	3	1	0	4	2020

i) PRE-REQUISITE: EE1U30G: Power Electronics.

ii) COURSE OVERVIEW: The goal of the course is to analyse the steady state equivalent modelling and AC circuit modelling of power electronic converters. It also includes the canonical modelling of converters. The course also imparts knowledge about the transfer function of the converter and controller design.

iii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO1	Develop DC-DC converters under steady state condition.	Apply
CO2	Explain dynamic modelling of switched power converters using state space averaging and circuit averaging techniques.	Understand
CO3	Develop converter transfer functions.	Apply
CO4	Analyse closed loop controllers for dc-dc power converters.	Analyse
CO5	Illustrate DC-DC converters operating in discontinuous conduction mode.	Understand

iv) SYLLABUS

Steady State Converter Analysis -Small-Ripple Approximation, Analysis of buck & boost converter in continuous & discontinuous conduction mode

Steady-State Equivalent Circuit modelling DC Transformer Model, Inductor voltage & capacitor voltage, inclusion of Semiconductor Conduction Losses in converters

AC Equivalent Circuit Modelling Small signal AC modelling of Buck Boost converter, Perturbation and Linearization, Construction of the Small-Signal Equivalent Circuit Model, Equivalent circuit model of a non-ideal flyback converter

State Space Averaging. State space averaging of non-ideal buck boost converter, Canonical Circuit Model of DC DC converters, modelling of pulse width modulator

Converter Transfer Functions. Frequency response analysis, Transfer Functions of the Buck-Boost Converter, graphical construction of converter transfer functions, Controller Design.

v) (a) TEXT BOOKS

1) Robert W Erickson, Dragan Maksimovic, Fundamentals of Power Electronics, Springer, 3rd edition, 2001.
2) Taylor Morey, Abraham Pressman, Keith Billings, Switching Power Supply Design, McGraw Hill, 3rd Edition, 2009.
3) Rashid M.H., Power Electronics Circuits, Devices and Applications, 3rdedition, Prentice Hall India, New Delhi, 2014.

(b) REFERENCES

1) Ned Mohan, Undeland, Robbins, Power Electronics: Converters, Applications and Design, 3rd ed., John Wiley, 2018.
2) Umanand L, Bhatt, Design of Magnetic Components for Switched Mode Power Converters, S R New Age International, New Delhi, 2001.
3) John. G.Kassakian, George C. Verghese, Principles of Power Electronics Addison-Wesley Publications, 1991.
4) Muhammad H. Rashid, "Power Electronics, Devices, Circuits and Applications", Pearson, 3rd edition, 2014.

vi) COURSE PLAN

Module	Contents	No. of hours
I	Fundamentals of Steady state converter modelling and analysis applied to basic dc-dc converters: Buck, boost and buck-boost converter - Principle of volt-sec balance, amp-sec balance, and small-ripple approximation - Steady-state (dc) equivalent circuits, losses and efficiency. Inclusion of semiconductor conduction losses in converter model.	**12**
II	Small-signal AC modelling - Averaging of inductor/capacitor waveforms - perturbation and linearisation. State-Space Averaging-Circuit Averaging and averaged switch modelling- Canonical Circuit Model - Manipulation of dc-dc converters' circuit model into Canonical Form-Modelling the pulse width modulator. (Treatment may be limited to ideal converters. Questions in the end semester examination may be limited to buck and boost converter).	**12**
III	Converter Transfer Functions - Review of frequency response analysis techniques - Bode plots - Converter transfer functions - graphical construction. Converter transfer functions of ideal buck, boost and buck-boost converters - Measurement of ac transfer functions and impedances.	**12**
IV	Controller Design: Effect of negative feedback on the network transfer functions - loop transfer function-Controller design specifications- PD, PI and PID compensators - applications to the basic dc-dc topologies - Practical methods to measure loop gains: Voltage and current injection.	**12**
V	Converters in Discontinuous Conduction Mode: AC and DC equivalent circuit modelling of the discontinuous conduction mode-Generalised Switch Averaging-small-signal ac modelling of the DCM switch network. Transfer functions of ideal buck and boost converters in DCM. *(Note: Questions in the end semester examination should not demand detailed derivations of transfer functions from scratch, as they're*	**12**

	quite lengthy. Instead, intermediate circuits/equations may be provided to ease the time required and test the procedure. Also, form of the transfer functions may be given and asked to interpret/draw bode diagrams).	
	Total hours	**60**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1H40C	CONTROL AND DYNAMICS OF MICROGRID	VAC	4	0	0	4	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: The goal of this course is to introduce the fundamental concepts of dynamics and control of microgrid. This course covers different control strategies for microgrid and their analysis.

iii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO1	Illustrate the basic concept of microgrid and its components	Apply
CO2	Compare different storage systems for microgrid applications	Understand
CO3	Outline the operating modes, interconnection standards and issues in microgrid	Understand
CO4	Infer various control strategies for microgrid	Understand
CO5	Model various components of microgrid	Apply

iv) SYLLABUS

Microgrid Concept –Components — Technical and Economic advantage of microgrids- Challenges and disadvantages of microgrid development.

Microgrids and Energy storage systems (ESS)- Application of energy storage systems in microgrids. PE interface design for energy storage system

Operation of microgrid in grid connected and islanded mode, Interconnection standards IEEE 1547 series, Integration issues of distributed generation – Power management in microgrids– Fault ride through capability of microgrid

Control architectures in microgrid, Basic control strategies, Coordinated control schemes in multi-microgrids, frequency, voltage regulations and volt-VAR support

Dynamic modelling of individual components in AC and DC microgrids, brief concept on the design of microgrid stabilizers to improve stability, Stability of hybrid AC/DC microgrid.

v) (a) TEXT BOOKS

1) H. Bevrani, B. François, T. Ise, “Microgrid Dynamics and Control”, John Wiley & Sons, 1st Edition, 2017.
2) 2. N. D. Hatziargyriou, “Microgrids Architecture and control”, IEEE Press Series, John Wiley & Sons Inc, 1st Edition, 2013.

(b) REFERENCES

1) S. Chowdhury, S P Chowdhury and P Crossely, "Microgrids and active distribution networks", IET Renewable energy series 6.
2) Suleiman M. Sharkh, Mohammad A. Abusara, "Power electronic converters for microgrid", IEEE Wiley
3) Amirnaser Yezdani, and Reza Iravani, Voltage Source Converters in Power Systems: Modeling, Control and Applications, IEEE John Wiley Publications, 2009.
4) Magdi S. Mahmoud, Microgrid: Advanced Control Methods and Renewable Energy System Integration, Elsevier, 2017.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Microgrids**- Microgrid Concept –Components – Micro sources, loads, power electronic interfaces - Architecture of microgrids (AC/DC/Hybrid AC/DC) – Technical and Economic advantage of microgrids- Challenges and disadvantages of microgrid development.	**12**
II	**Microgrids and Energy storage systems (ESS)-** Different types of Batteries- Advanced lead acid battery, Flow battery, battery performance, storage density, Fuel cell, Flywheel, Supercapacitor, Pumped hydro storage, Superconducting magnetic energy storage, Compressed air energy storage system, Thermal energy storage — Application of energy storage systems in microgrids. PE interface design for energy storage system.	**13**
III	**Operation of microgrid in grid connected and islanded mode** – AC microgrid, DC microgrid, Hybrid AC/DC microgrid – Interconnection standards IEEE 1547 series, Integration issues of distributed generation **Power management in microgrids**– Fault ride through capability of microgrid.	**11**
IV	**Control architectures in microgrid** – Master slave with power-based control, Hierarchical control with centralized and distributed control - Basic control strategies – PQ control, V/f control, Droop control – Advanced control techniques- Coordinated control schemes in multi-microgrids, frequency, voltage regulations and volt-VAR support.	**13**
V	**Dynamic modelling of individual components in AC and DC microgrids** – Voltage source converter model, DC/DC converter model, line model, load model - state space model analysis and influence of system parameters on the microgrid dynamics - brief concept on the design of microgrid stabilizers to improve stability, Stability of hybrid AC/DC microgrid.	**11**
	Total hours	**60**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
EE1H40D	SMART GRID AND INTERFACING	VAC	4	0	0	4	2020

i) PRE-REQUISITE: Nil.

ii) COURSE OVERVIEW: The course aims to provide students with a conceptual introduction to smart grids, its architecture, components and communication technologies. It also aims to provide an insight about the need for energy storage, devices and technologies available and their applications.

iii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO1	Summarize the need, benefits and functions of Smart Grid and its various components.	Understand
CO2	Explain the various Smart Grid Technologies.	Understand
CO3	Identify the functions of mobile electrical storage systems and explain the need for hybrid energy storage.	Apply
CO4	Explain the concepts of IoT and its protocol	Understand
CO5	Explain the communication and computing technologies in Smart Grid.	Understand
CO6	Enumerate the need, benefits and functions of Smart Grid and its various components.	Understand

iv) SYLLABUS

Evolution of Electric Grid-Conventional Grid vs Smart Grid - Benefits, Challenges and Key Application Areas of Smart Grid. Smart Grid Reference Architecture-Introduction to Smart Meters, Real Time Pricing Smart Substations, Substation Automation, IEC 61850 Substation Architecture, Smart Appliances, Smart Sensors, Home & Building Automation.

Role of Energy storage Systems-Applications - Overview of energy storage technologies, Comparison of Various Storage Technologies-Criteria for Selection of Storage. Mobile Storage Systems, Basic concepts of Hybrid Energy storage systems.

Physical Design of IoT: Things in IoT, IoT Protocols. Energy management and smart grid applications of IoT. Communication Networks for Smart Grid, Communication Protocols. Cloud architecture of smart grid.

v) (a) TEXT BOOKS

1) Stuart Borlase “Smart Grid Infrastructure Technology and Solutions”, CRC Press; 2nd edition.
2) James Momoh, “Smart Grid: Fundamentals of Design and Analysis”, Wiley, 2012.
3) S. Chowdhury, “Microgrids and Active Distribution Networks.” Institution of Engineering and Technology, 2009.

4) Janaka Ekanayake, Kythira Liyanage, Jianzhong Wu, Akihiko Yokohama, Nick Jenkins- "Smart Grids Technology and Applications", Wiley, 2012.

(b) REFERENCES

1) Barker, Preston, Price, Rudy F., "Cybersecurity for the Electric Smart Grid: Elements and Considerations", Nova Science Publishers Inc, 2012.
2) Eric D. Knapp, Raj Samani, "Applied Cyber Security and the Smart Grid: Implementing Security Controls into the Modern Power Infrastructure", Syngress; 1st edition (26 February 2013).
3) Richard J. Campbell, "The Smart Grid and Cybersecurity: Regulatory Policy and Issues", Congressional Research Service, 2011.
4) Dariusz Kloza, Vagelis Papakonstantinou, Sanjay Goel, Yuan Hong, "Smart grid security", Springer.
5) Roger C. Dugan, "Electrical Power Systems Quality", McGraw-Hill Publication, 3/e.
6) G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, 2/e.

vi) COURSE PLAN

Module	Contents	No. of hours
I	**Introduction to Smart Grid**: Evolution of Electric Grid- Conventional Grid vs Smart Grid -Need and Definitions of Smart Grid-Benefits, Challenges and Key Application Areas of Smart Grid. **Smart Grid Components:** Smart Grid Reference Architecture- Introduction to Smart Meters, Real Time Pricing- Intelligent Electronic Devices (IED) and their application for monitoring & protection, Wide Area Measurement System (WAMS), Phase Measurement Unit (PMU)	**12**
II	**Smart Grid Technologies:** Smart Substations, Substation Automation, IEC 61850 Substation Architecture, Smart Appliances, Automatic Meter Reading (AMR), Advanced Metering Infrastructure (AMI) Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation.	**13**
III	**Energy Storage Technologies**: Role of Energy storage Systems- Applications - Overview of energy storage technologies - Thermal, Mechanical, Chemical, Electrochemical, Electrical - Comparison of Various Storage Technologies-Criteria for Selection of Storage. **Mobile Storage Systems**: Electric Vehicle, G2V, V2G. Basic concepts of Hybrid Energy storage systems.	**12**
IV	**Introduction to IoT**: Definition and Characteristics of IoT, Physical Design of IoT: Things in IoT, IoT Protocols. **IoT applications in Smart Grid**: Energy management and smart grid applications. IoT based home automation, Smart metering for electricity consumers. IoT based weather stations, Automobile IoT- Electric vehicles-platform and software.	**11**

V	**Communication Networks for Smart Grid**: Interoperability and connectivity - Home Area Network (HAN), Neighborhood-Area Networks (NANs), Sensor and Actuator Networks (SANETs)-Communication Protocols. **Cloud computing in Smart Grid**: Private, public and Hybrid cloud. Cloud architecture of smart grid.	**12**
	Total hours	**60**

vii) CONTINUOUS ASSESSMENT EVALUATION PATTERN

Attendance	:	10 marks
CA Exams (2 numbers)	:	25 marks
Assignment/Project/Case study etc.	:	15 marks
Total	:	**50 marks**

viii) MARK DISTRIBUTION

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours